Correlation of the SAGE III on ISS Sensor Assembly Thermal Model to Thermal Vacuum Testing

Ruth M. Amundsen
NASA Langley Research Center

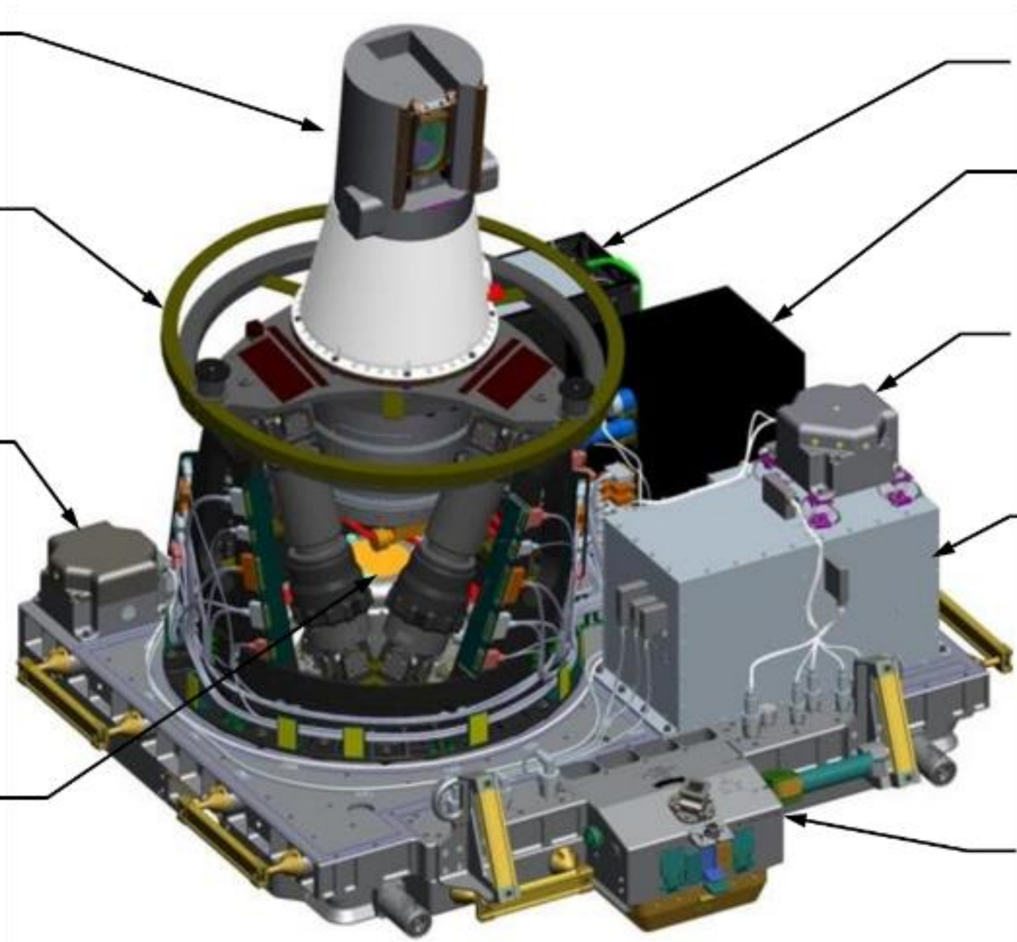
TFAWS15-PT-12

THERMAL & FLUIDS ANALYSIS WORKSHOP
GSFC · 2015

Agenda

- Background
- SAGE III thermal model
- Sensor assembly
- TVAC test setup
- Model complexities
- Thermal model correlation
- Conclusion

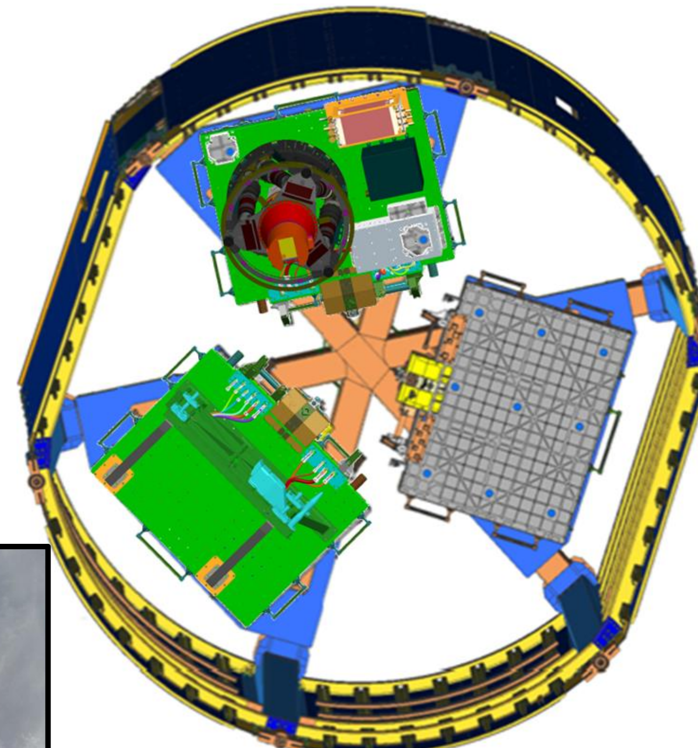
SAGE III Instrument Payload



Launch on SpaceX

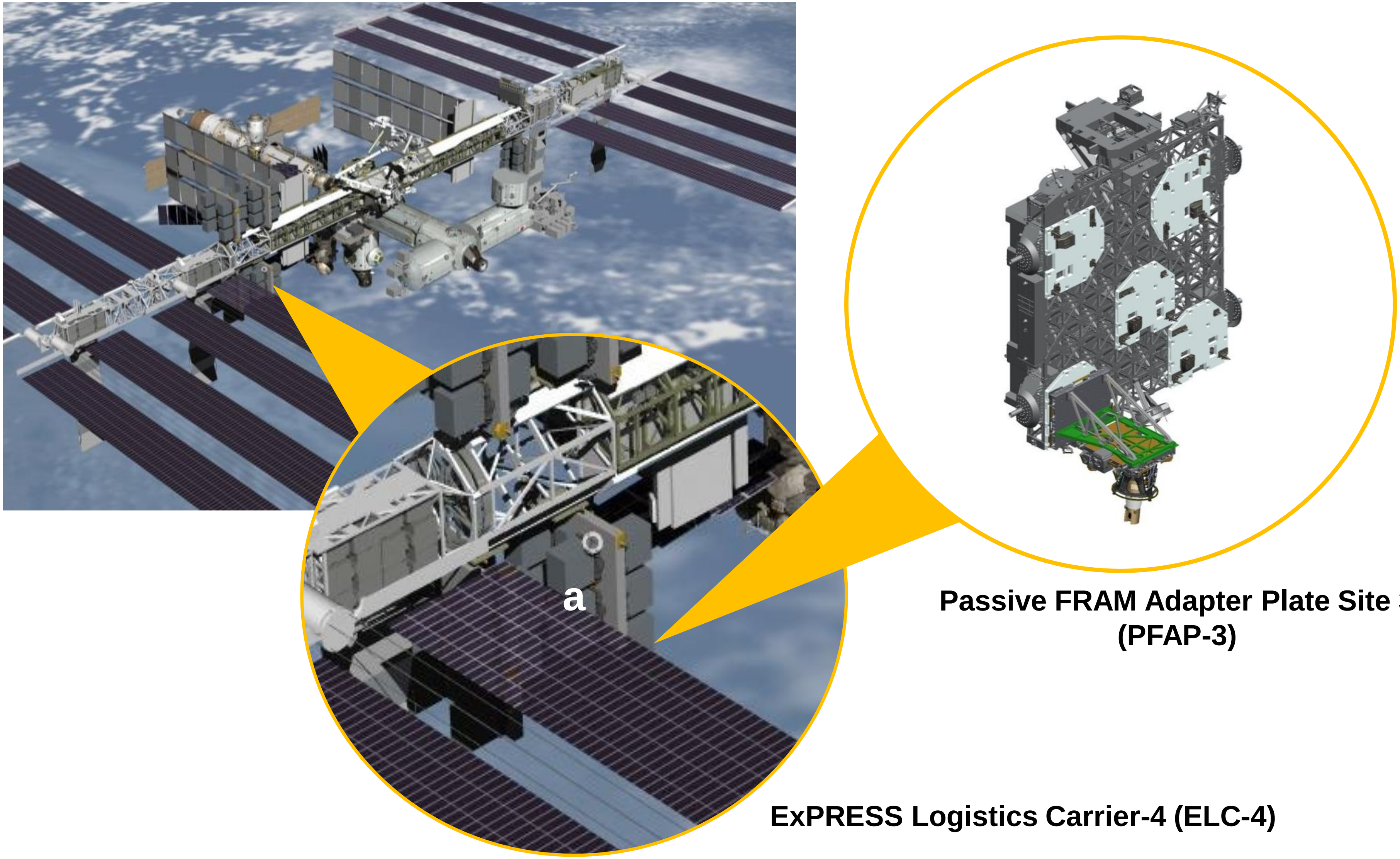

Integration Hangar

Dragon Unpressurized Cargo Module



SAGE III on ISS

S3 Truss Payload Attachment System-4 Site (PAS-4)

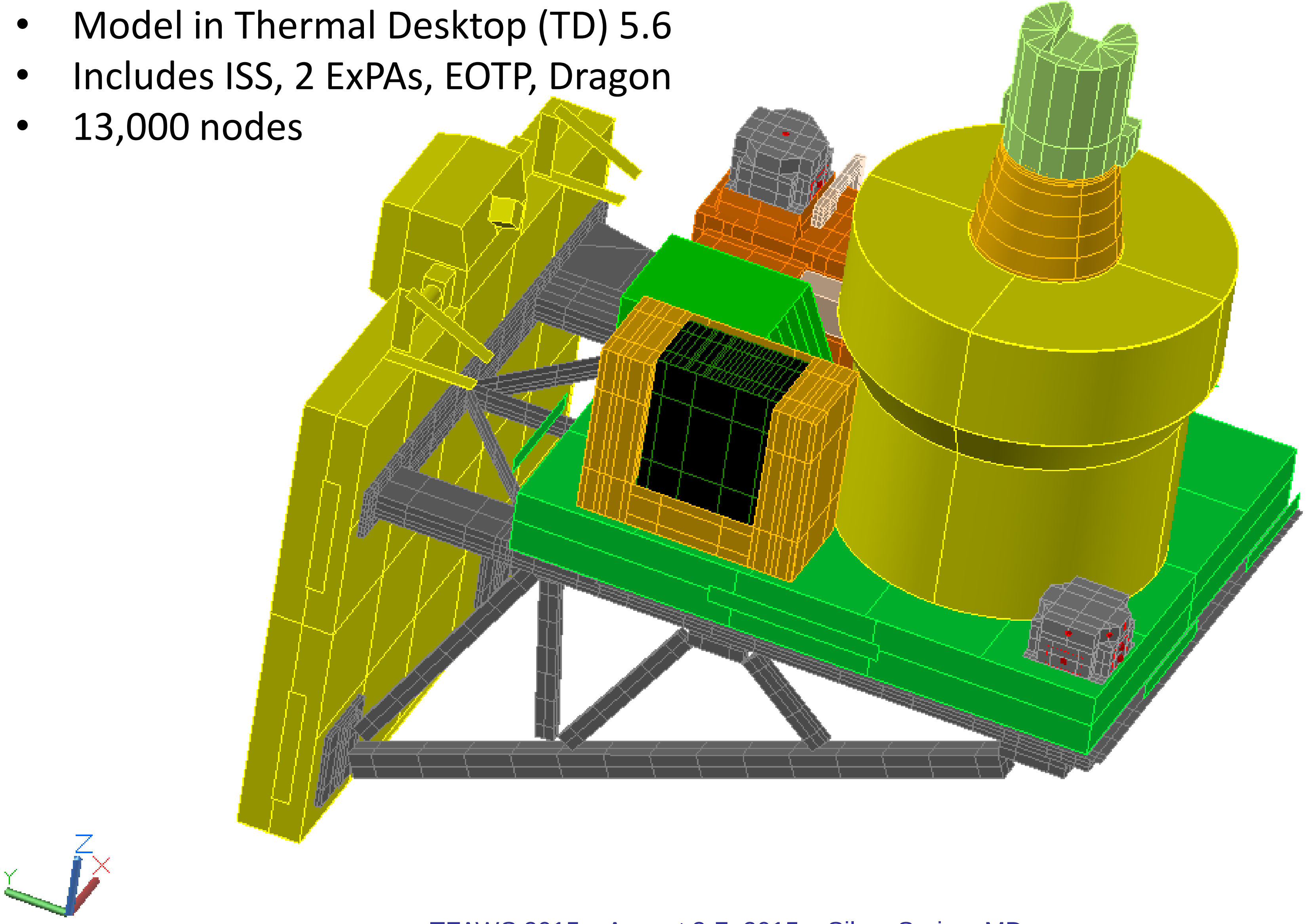


Passive FRAM Adapter Plate Site 3 (PFAP-3)

ExPRESS Logistics Carrier-4 (ELC-4)

SAGE III Thermal Model

- Model in Thermal Desktop (TD) 5.6
- Includes ISS, 2 ExPAs, EOTP, Dragon
- 13,000 nodes

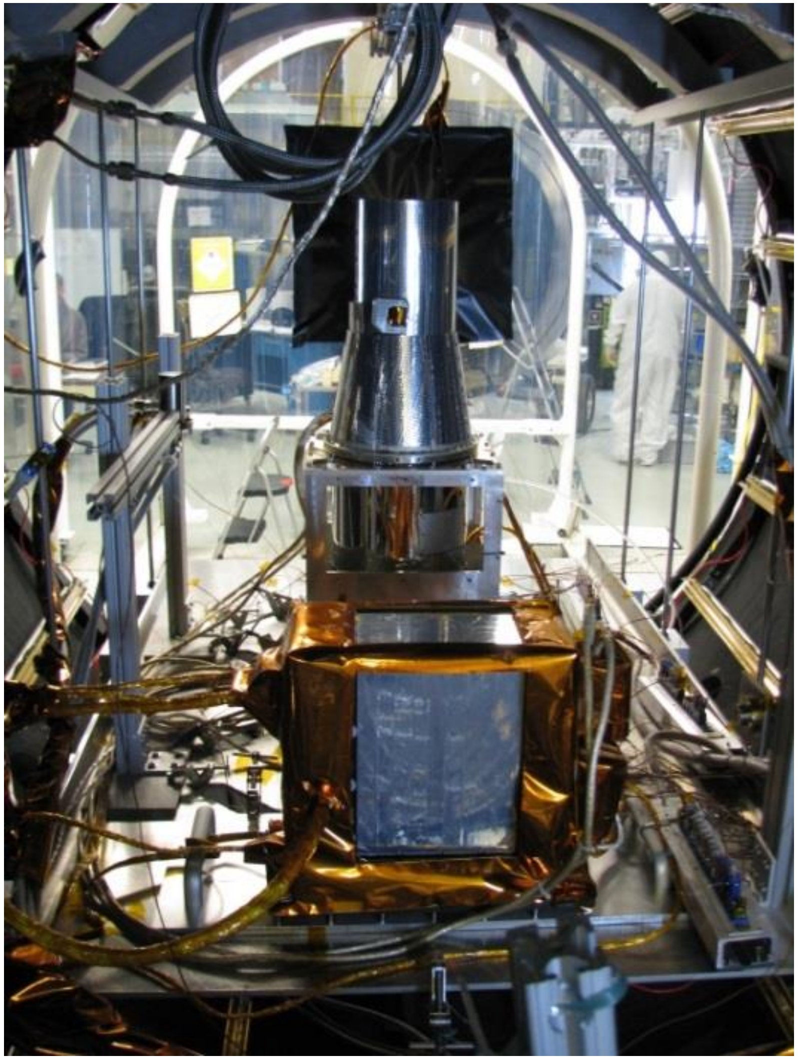


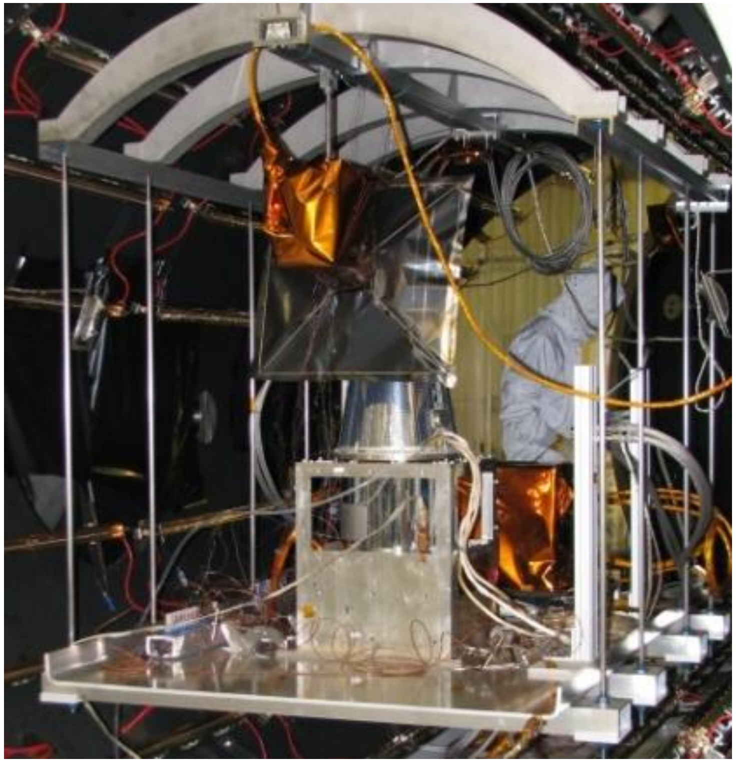
Heritage Flight Hardware

- SAGE III has been maintained at NASA LaRC
- Hexapod has been maintained at Thales Alenia Space – Italia (TAS-I) in Turin, Italy
- Hardware is >20 years old

	
Sage III Instrument	Hexapod Pointing System

8x15’ Thermal Vacuum Chamber



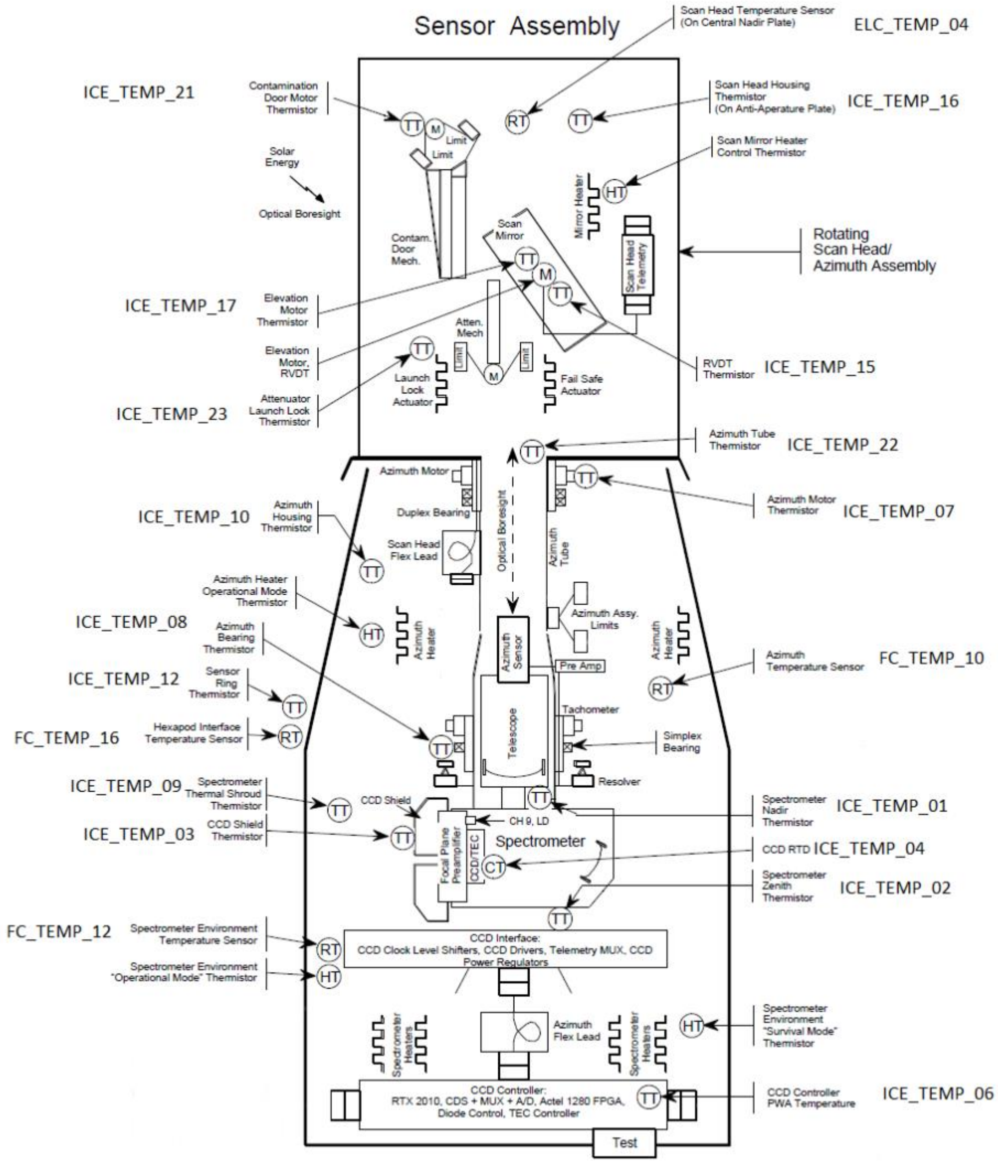


- Instrument TVAC testing at LaRC
- Nov 2014 – March 2015
- Unpowered, heater-only, and powered balances, hot and cold

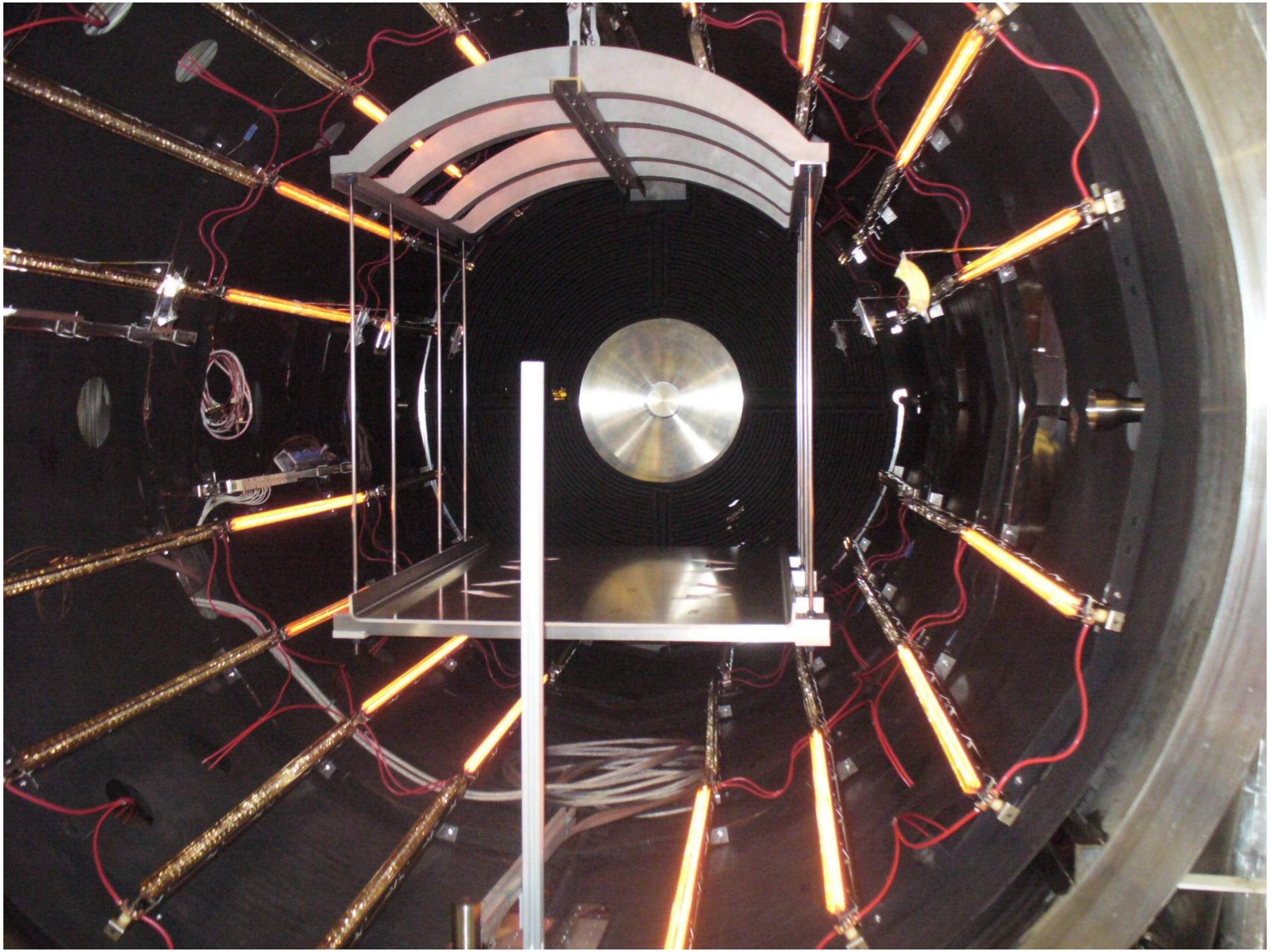
Thermal Model Complexities

- Heritage hardware
- Lamps in TVAC
- Thermo-electric cooler
- Elevation motor power

Sensor Assembly Configuration



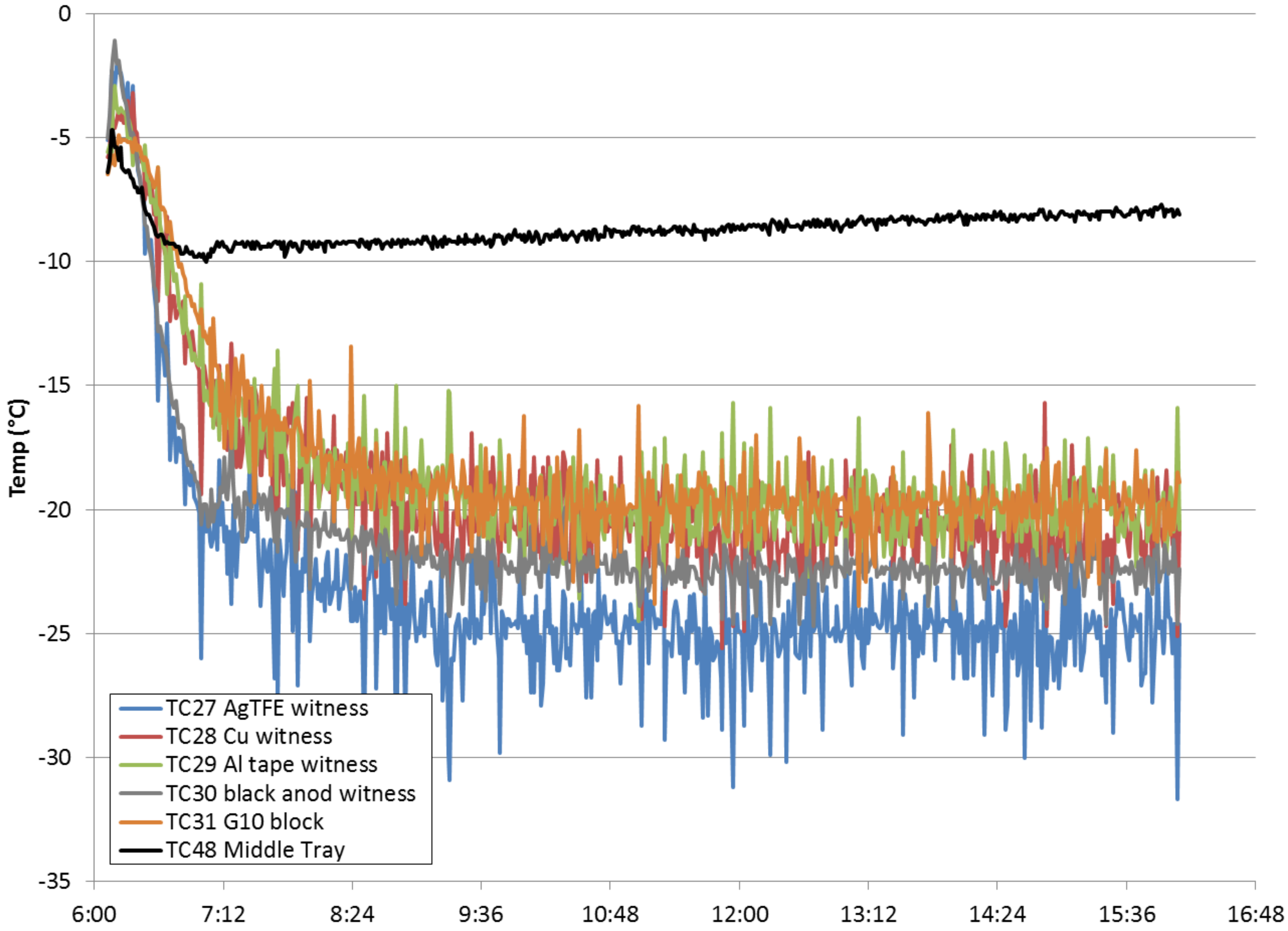
“IR” Lamps in TVAC



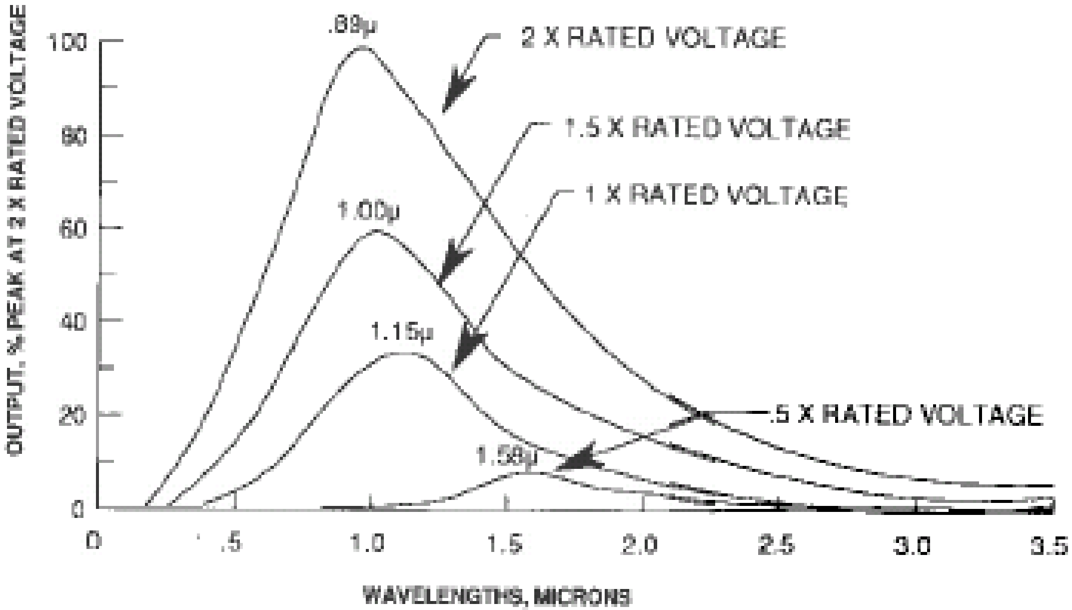
Lamp Issues

- Control noise
- Lack of stable power measurement
- Solar spectrum fraction varies with voltage
  - Difficult to run transient with changing chamber environment
  - Radiation conductors (radks) must be run in solar as well as IR
  - Rays shot from each lamp bank in separate radk case
  - Difficult to determine solar fraction
  - Some TVAC surfaces did not have measured solar absorptivity (α)

Thermal Noise due to Lamp Control



Solar Spectrum of Lamps



POWER DISSIPATION VS. VOLTAGE FORMULA

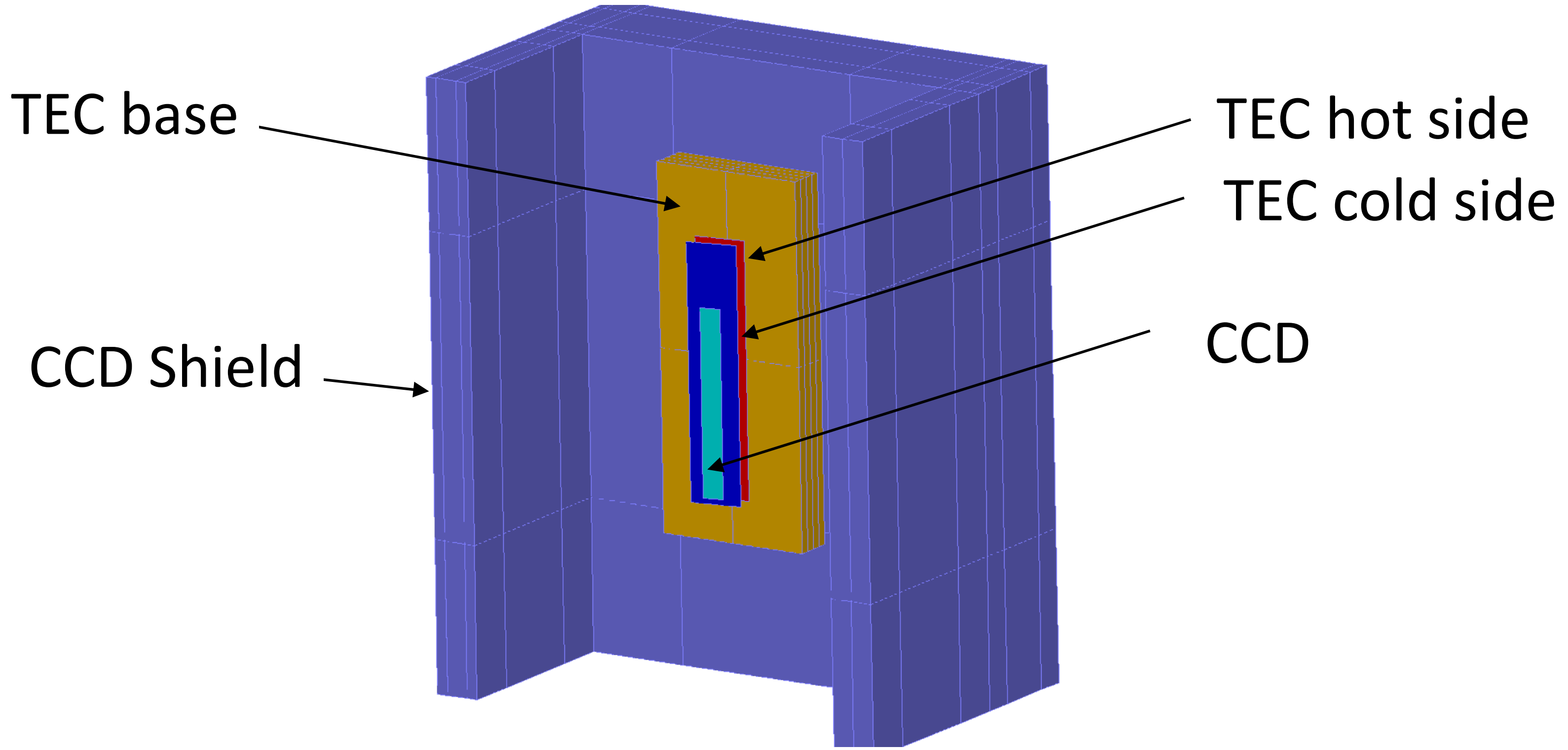
$$\frac{w}{W} = \left(\frac{v}{V}\right)^{1.54}$$

$$w = W\left(\frac{v}{V}\right)^{1.54}$$

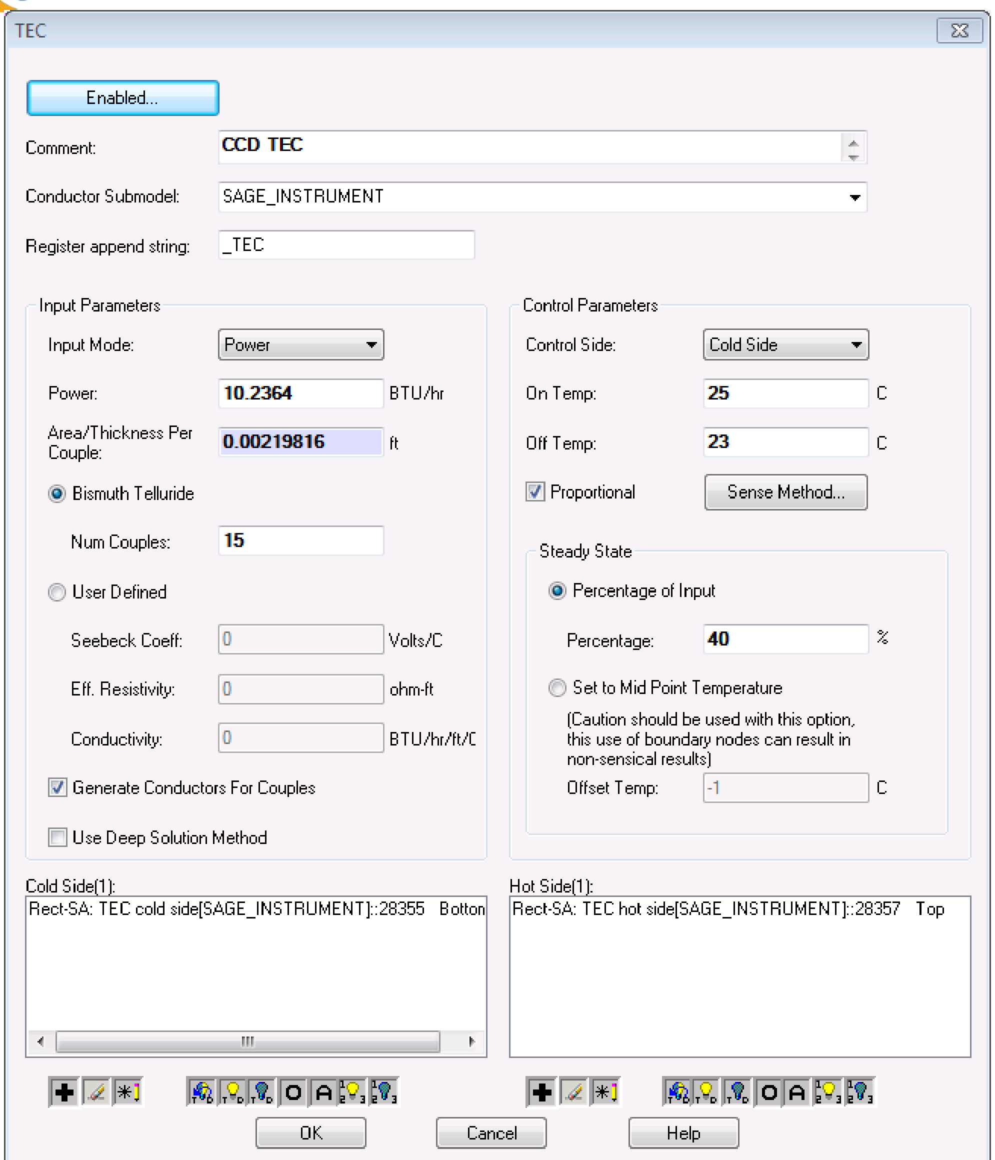
w = Power Dissipated, Watts
W = Rated Power, Watts

v = Lamp Voltage, Actual
V = Lamp Voltage, Rated

Thermo-electric Cooler

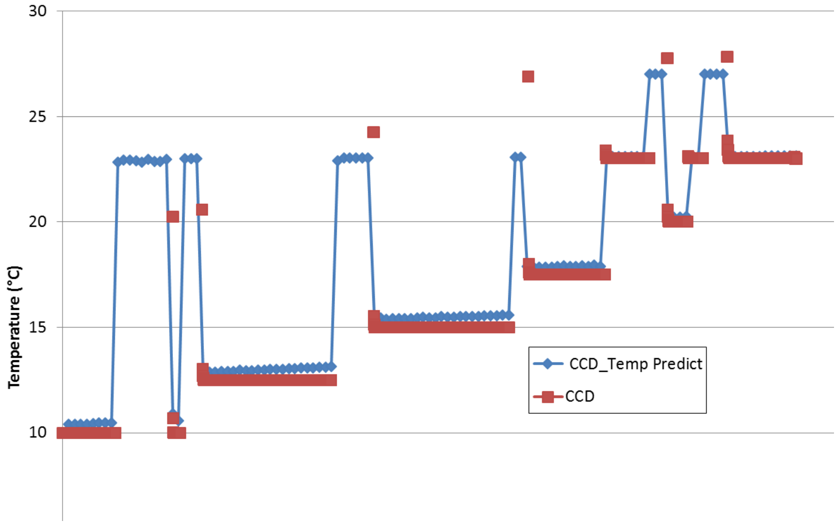


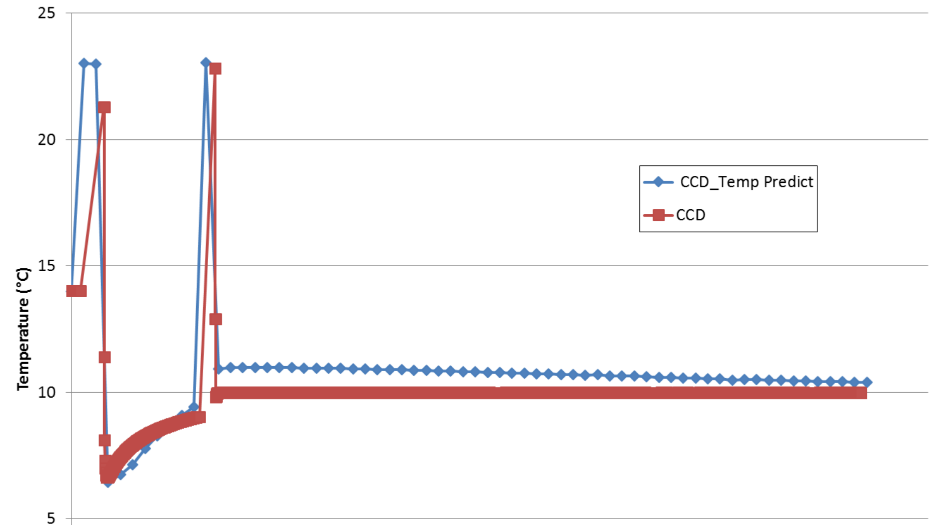
TEC Implementation in TD

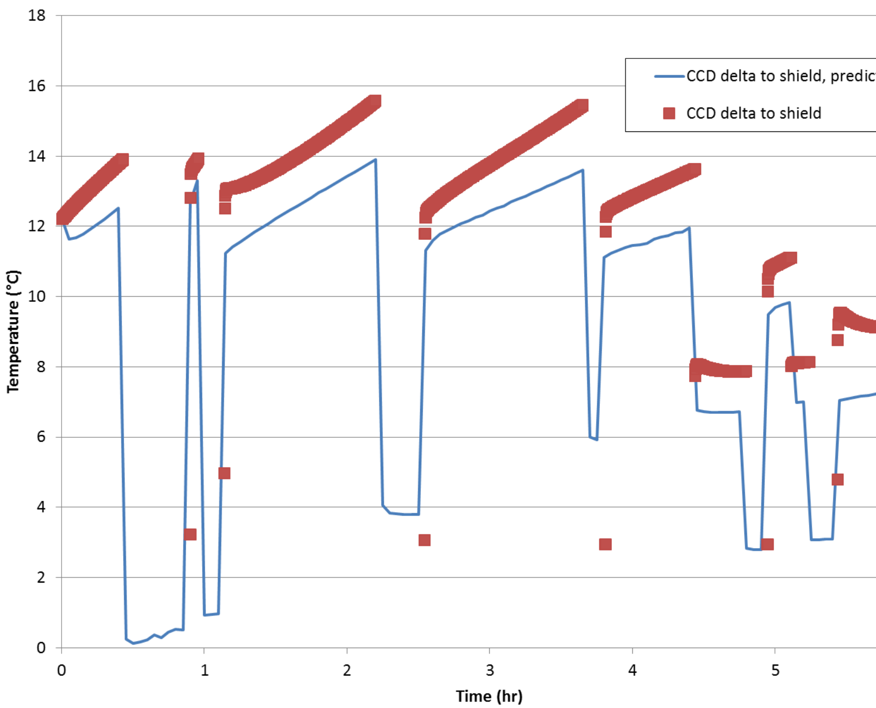


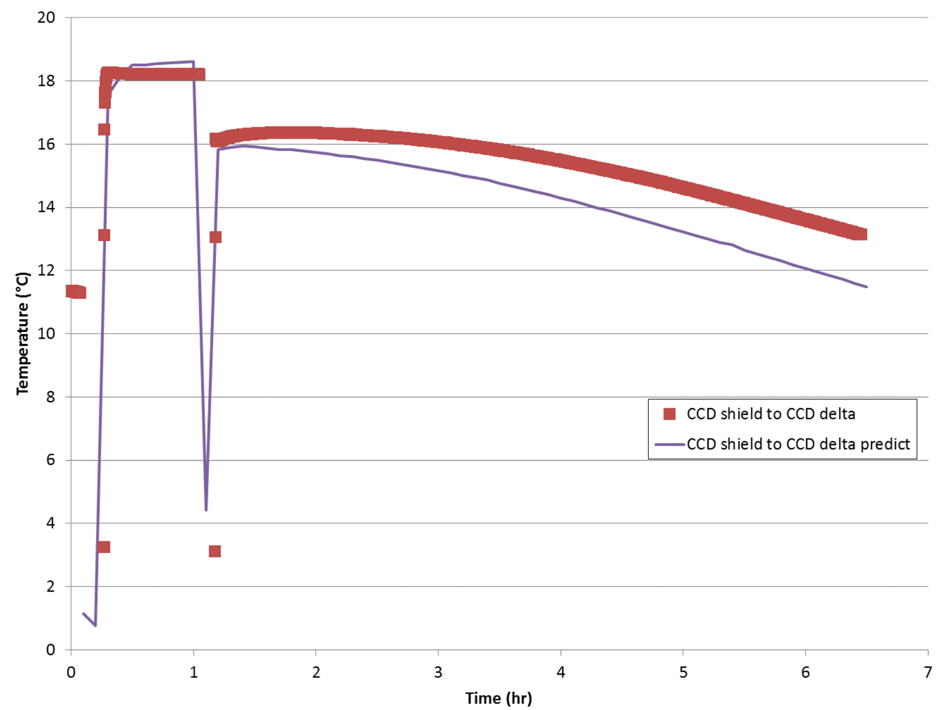
- Test data showed TEC held delta of 18°C (original spec >50°C)
- Back conductor used to account for TEC degradation
- Symbols used for all control variables to allow parametric runs
- Four cases with TEC setpoint changes used for correlation

TEC Correlation

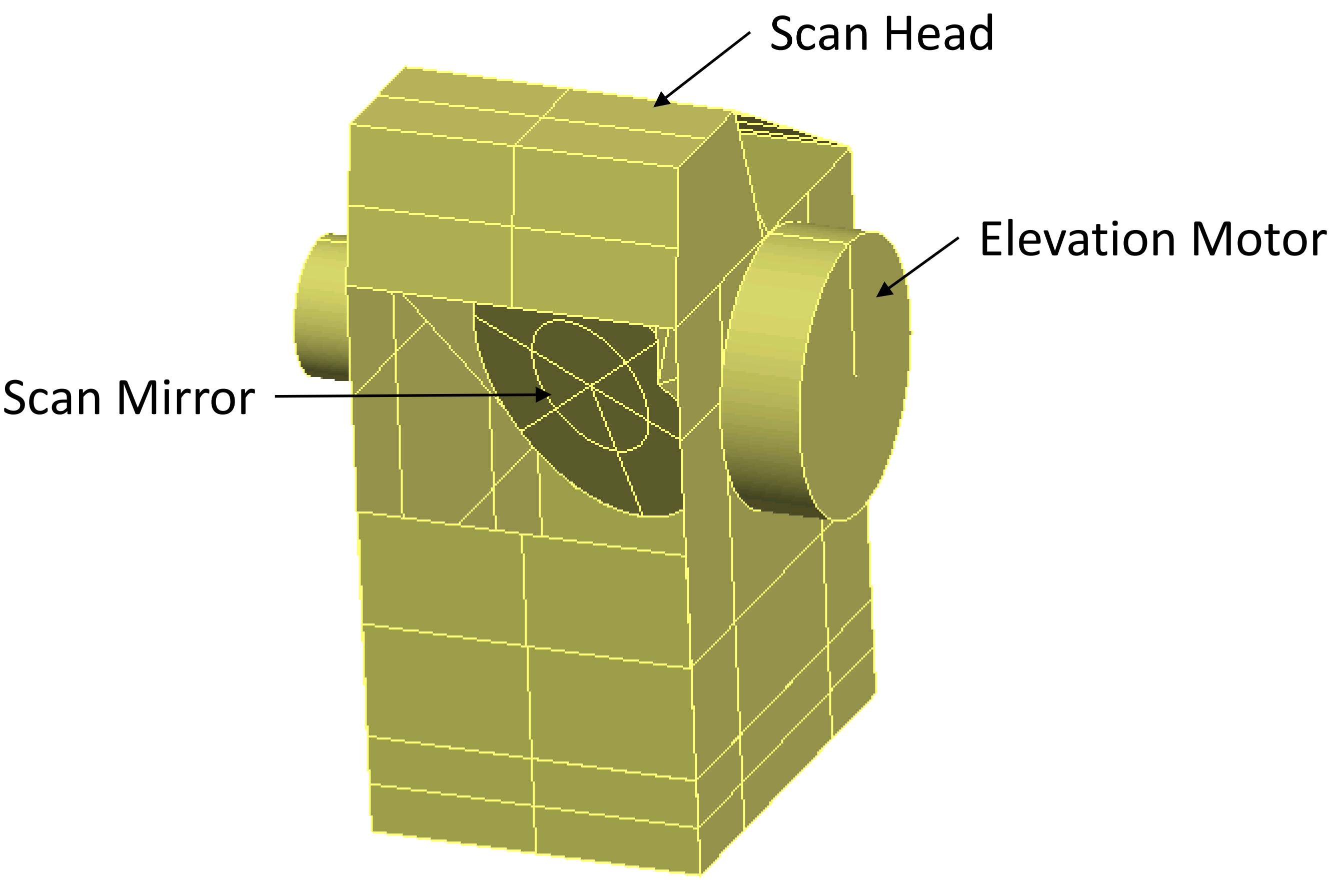




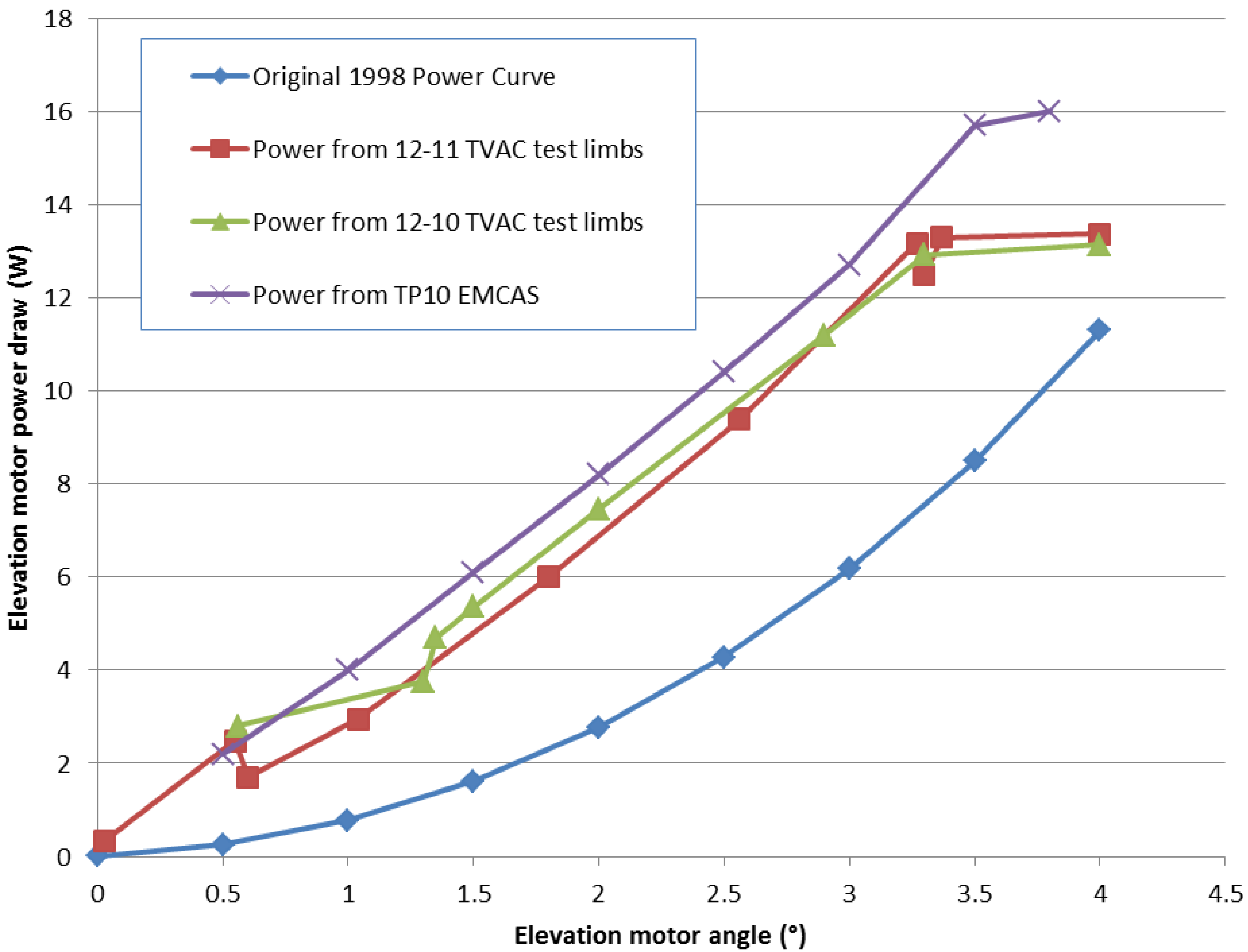




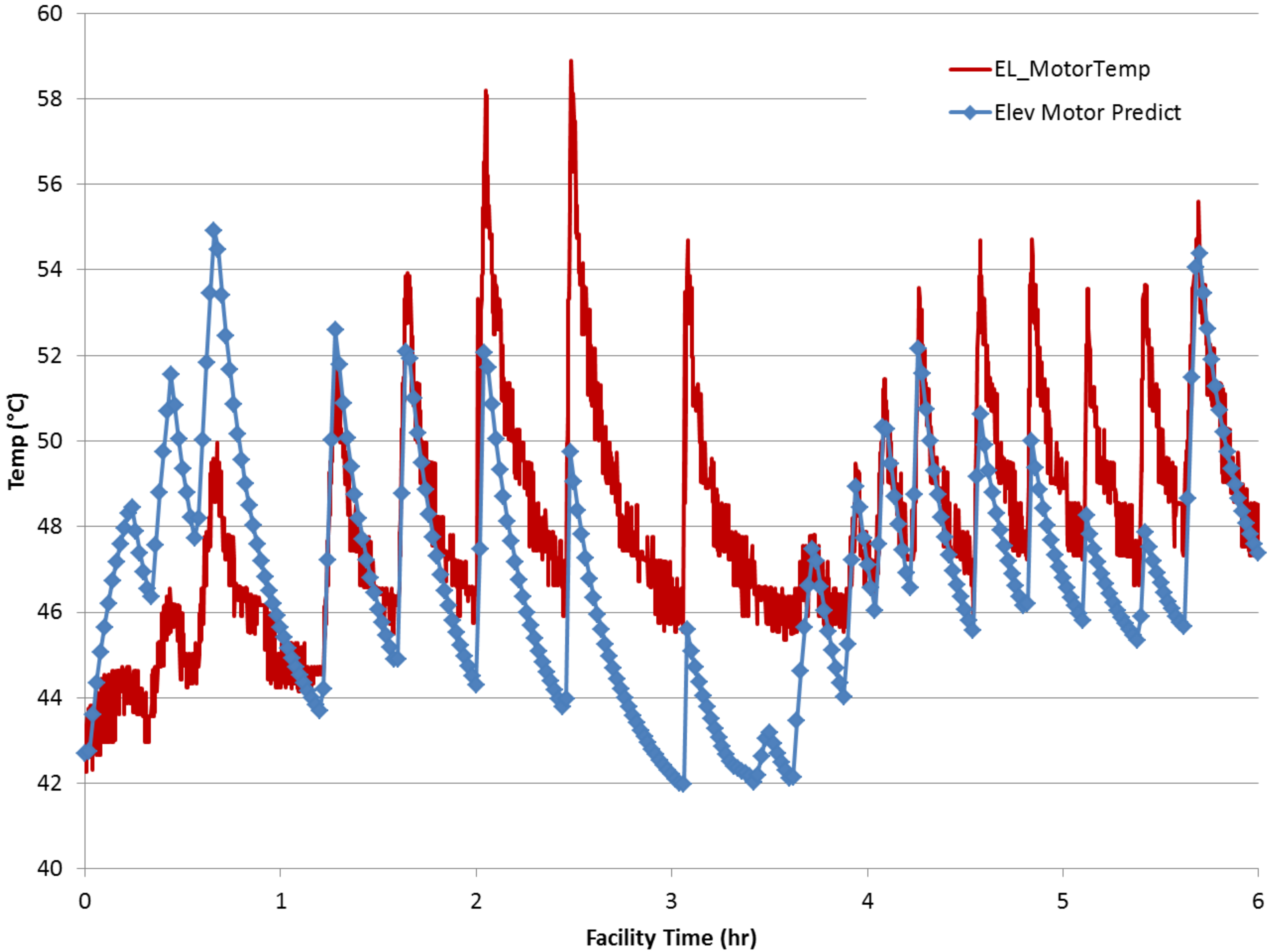
Elevation Motor



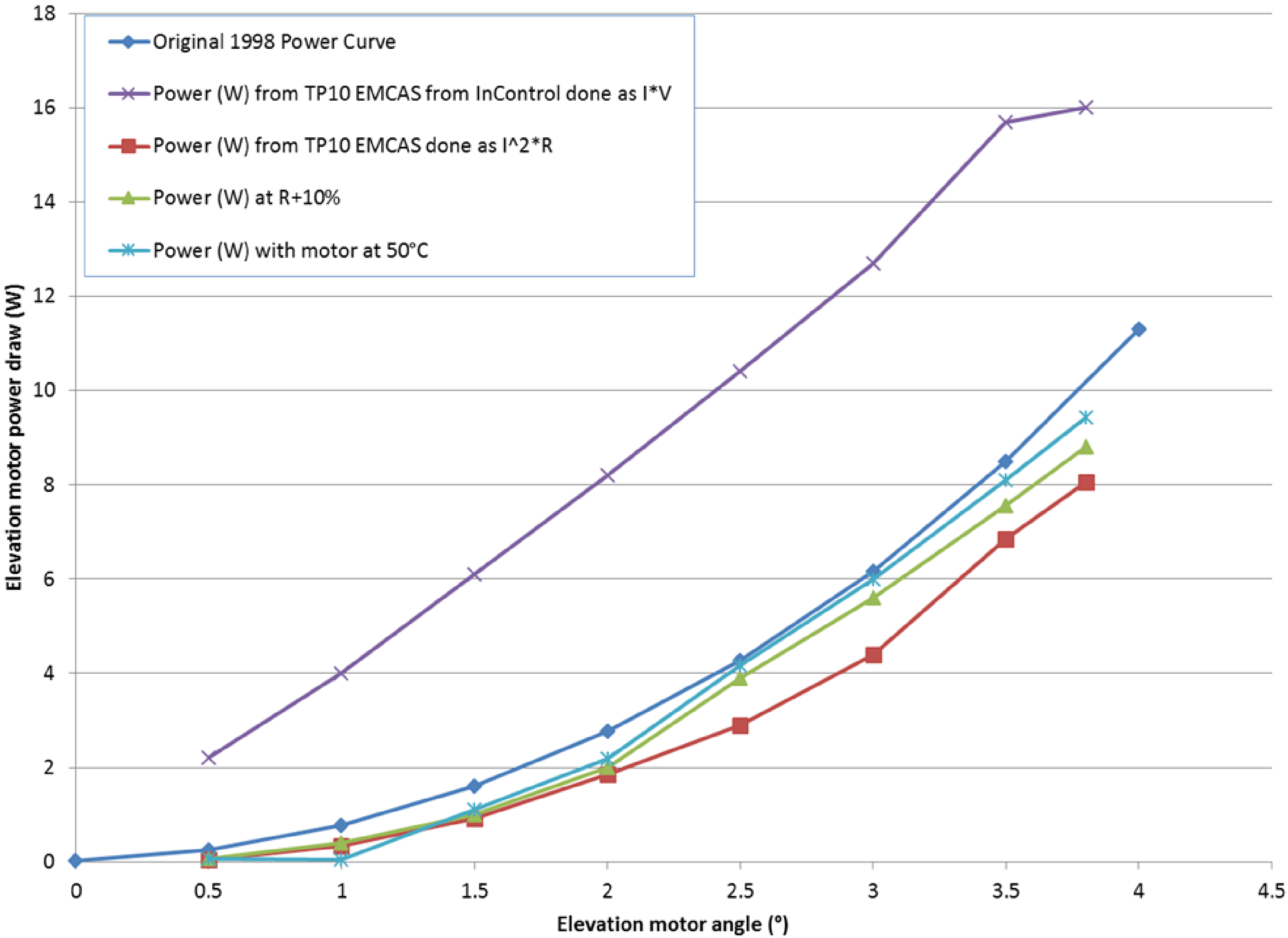
Elevation Motor Power – Initial Measurements



Initial Correlation to Elevation Motor Events

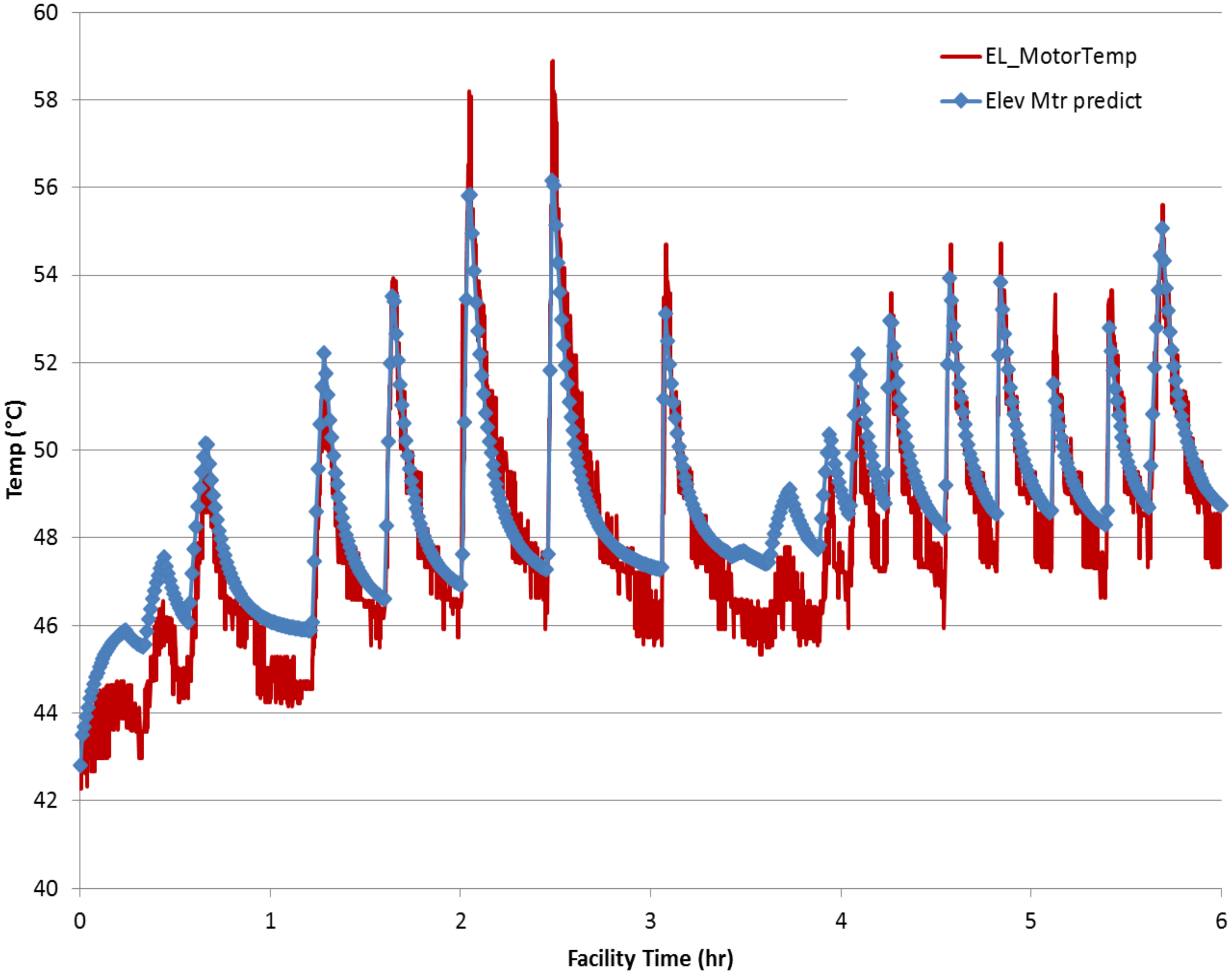


Elevation Motor Power - Actual

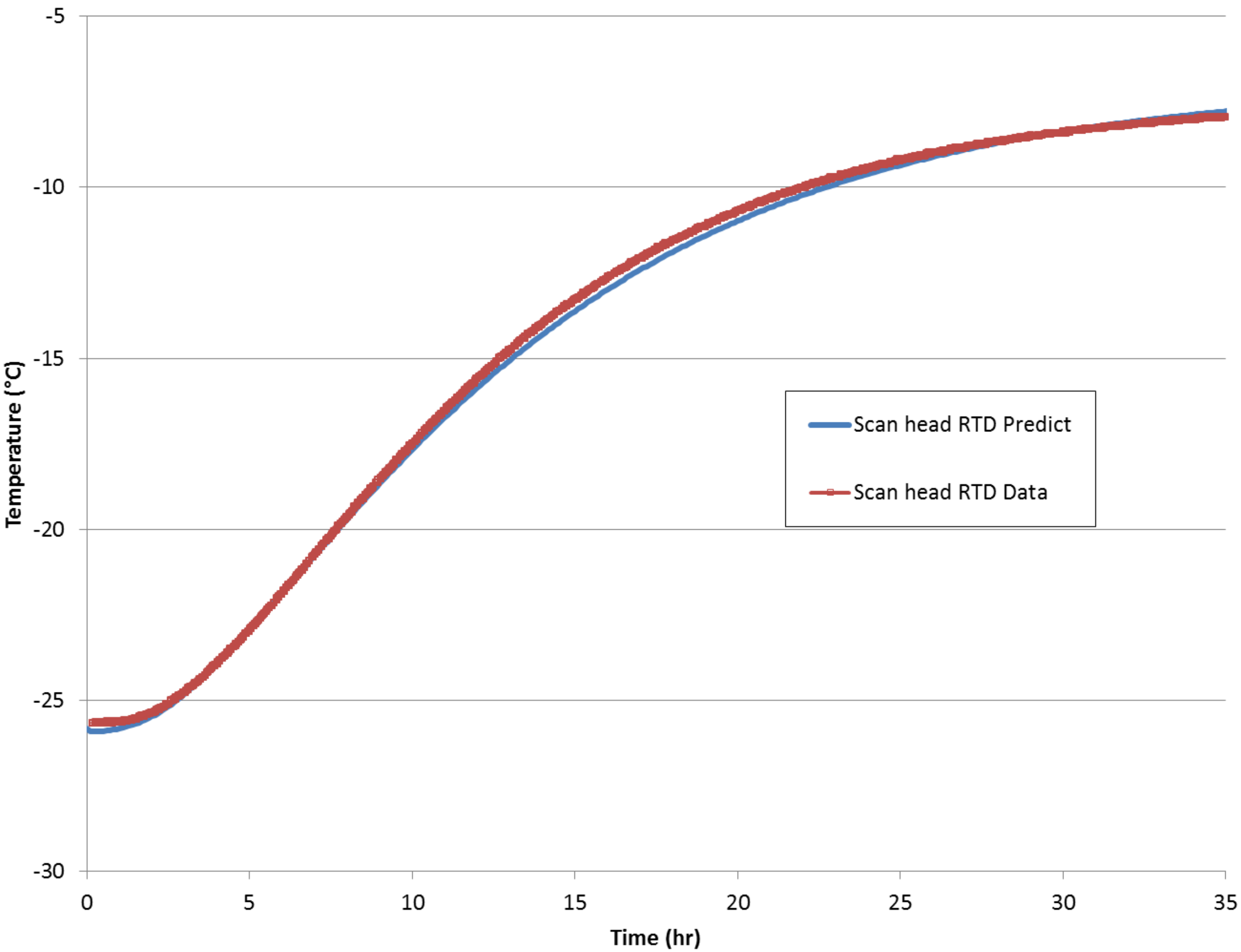


- This is a case where Power ≠ I * V (instead, $P = I^2R$)

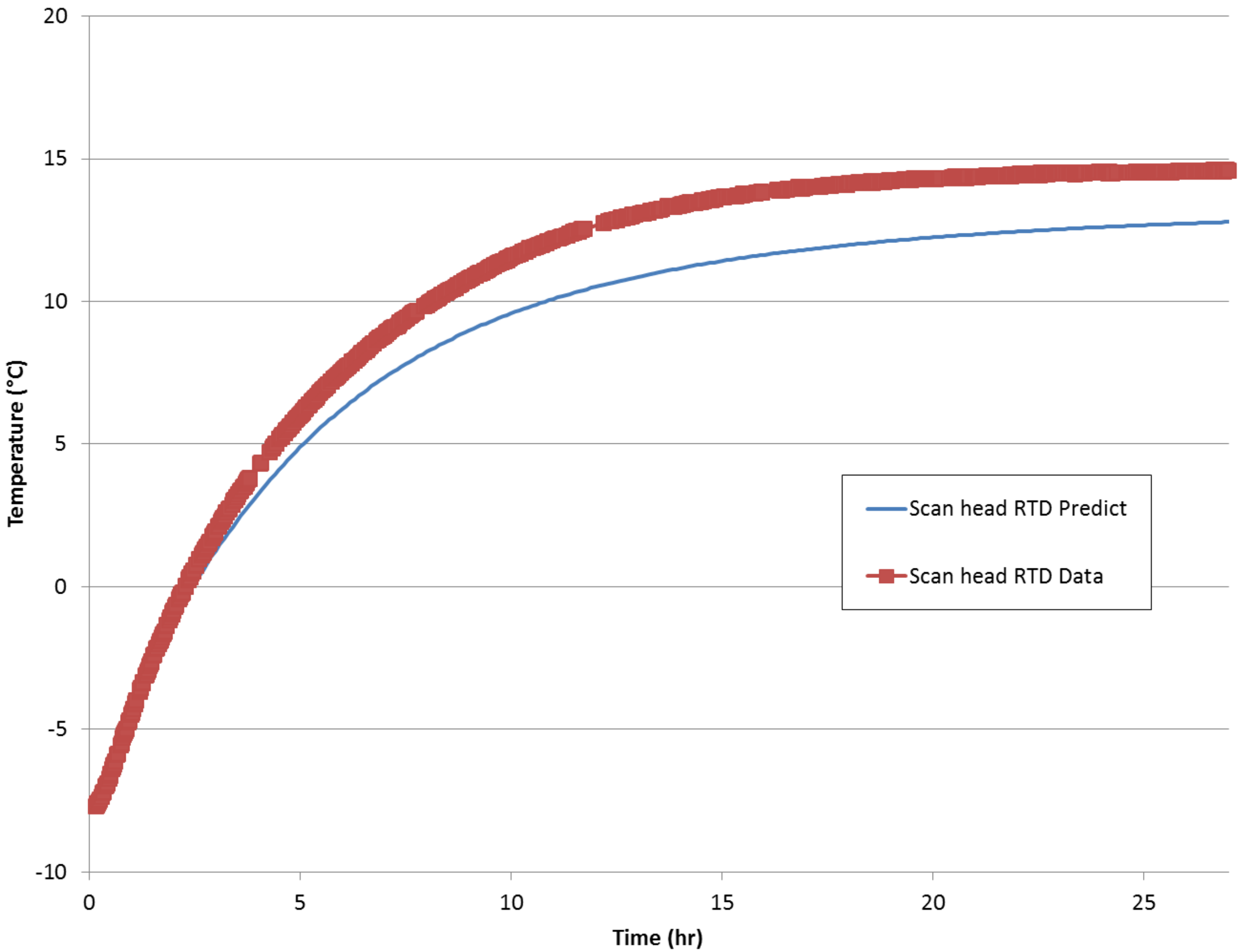
Final Correlation to Elevation Motor Events



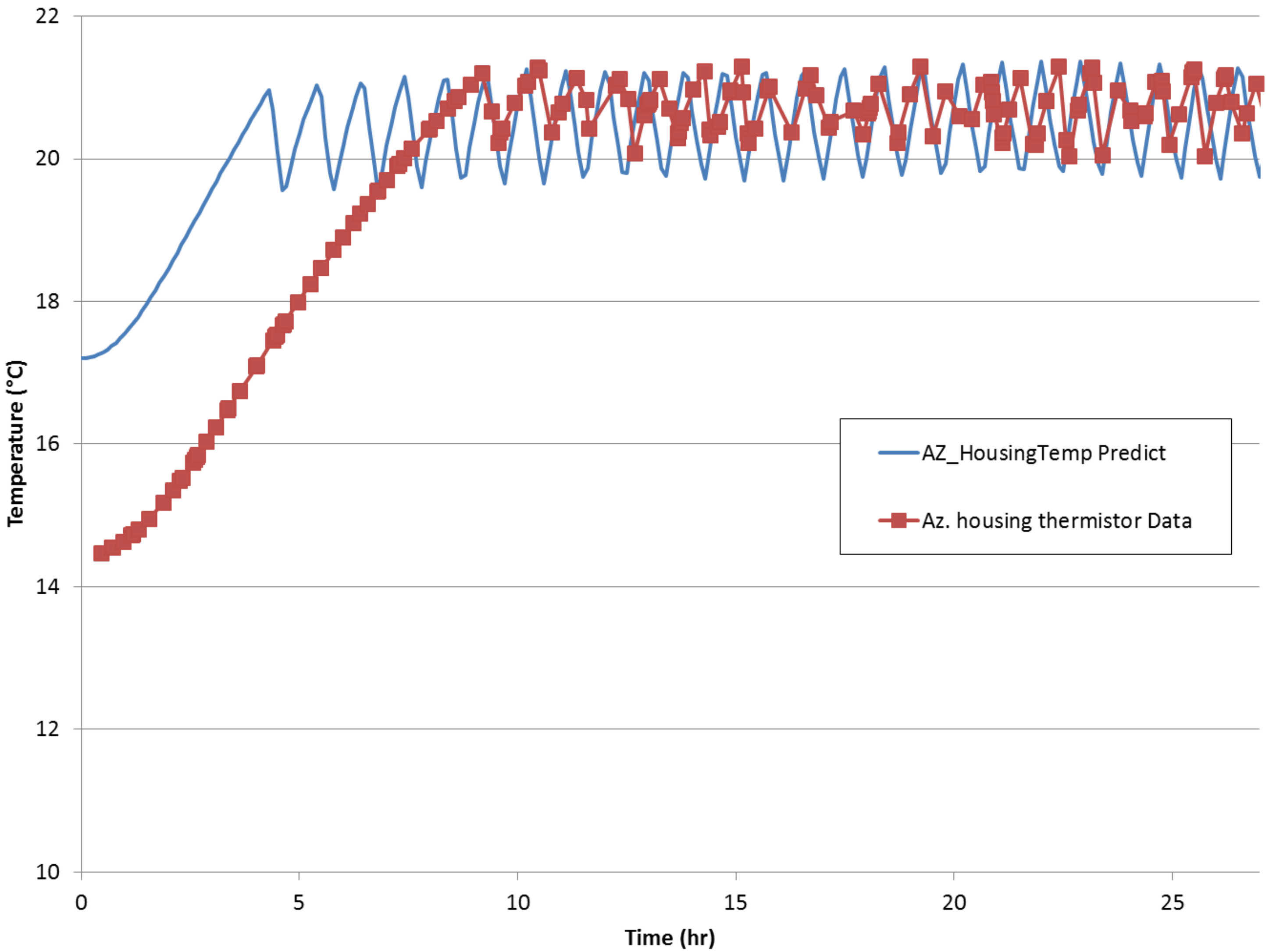
Example of Heater-Only Balance Transient



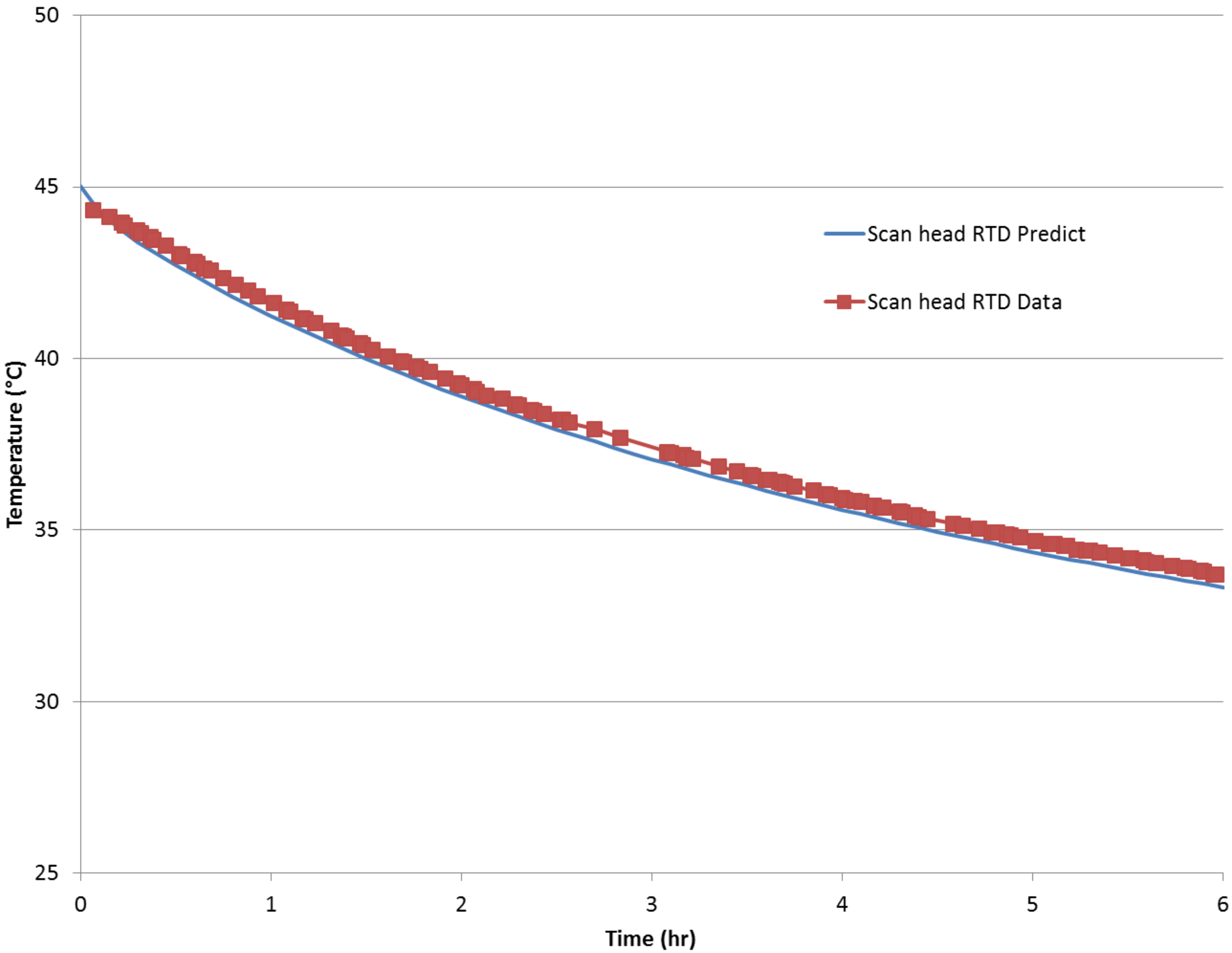
Example Powered Transient to Cold Balance



Example Correlation of Heater-Controlled Part



Example Unpowered Cooldown Correlation



Summary Correlation Results

	Hot powered transient	Hot cooldown	Cold powered transient	Cold cooldown	Overall error
Overall RMS error (°C)	1.4	0.5	2.7	1	1.4
Avg error (°C)	-0.2	0.2	0.9	-0.6	0.1
Flight sensor RMS error (°C)	1.5	0.5	1.6	1.2	1.2

RMS error calculated over all sensors, entire transient timeline

Conclusions

- Quartz “IR” lamps in TVAC make correlation difficult
- TD implementation of TEC effective
- Power not always I*V, depending on component
- Heritage hardware/model feasible to correlate well
- Heater-only balance extremely useful in correlation
- Unpowered cooldown extremely useful in correlation

Backup

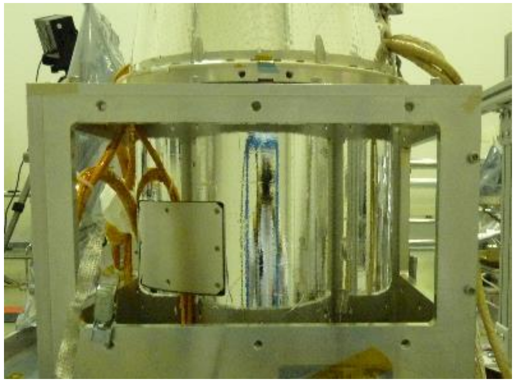
Major Model Changes in Correlation

- Measured solar α for TVAC aluminum/steel parts
- Emissivity and ε^* for crushed MLI
- Motor powers
- TEC power and back-conductor
- Solar lamp fraction
- TVAC shroud temperatures
- Contact for GSE hardware to TVAC tray
- Mass factors for cabling
- Heater control location
- Scan head position

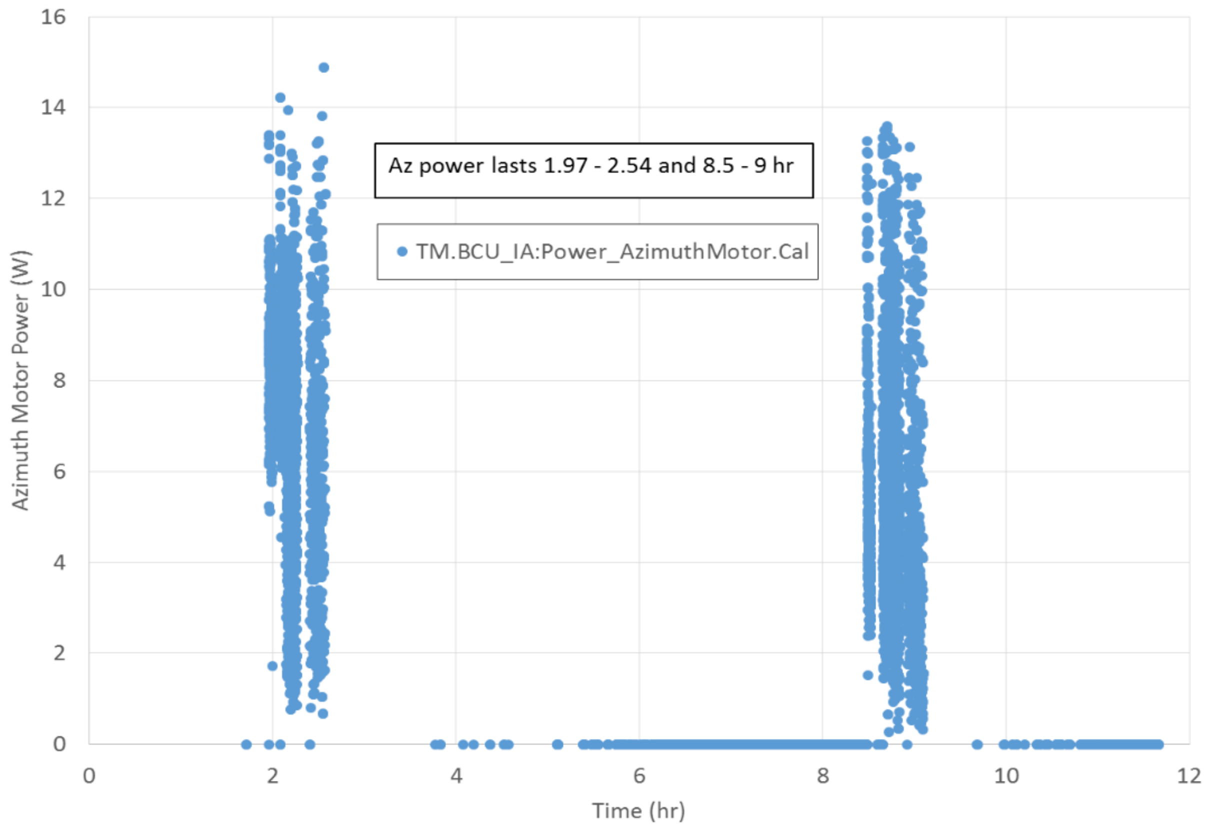
Sensor Assembly Hardware

Scan head and azimuth assemblies covered in perforated silver Teflon

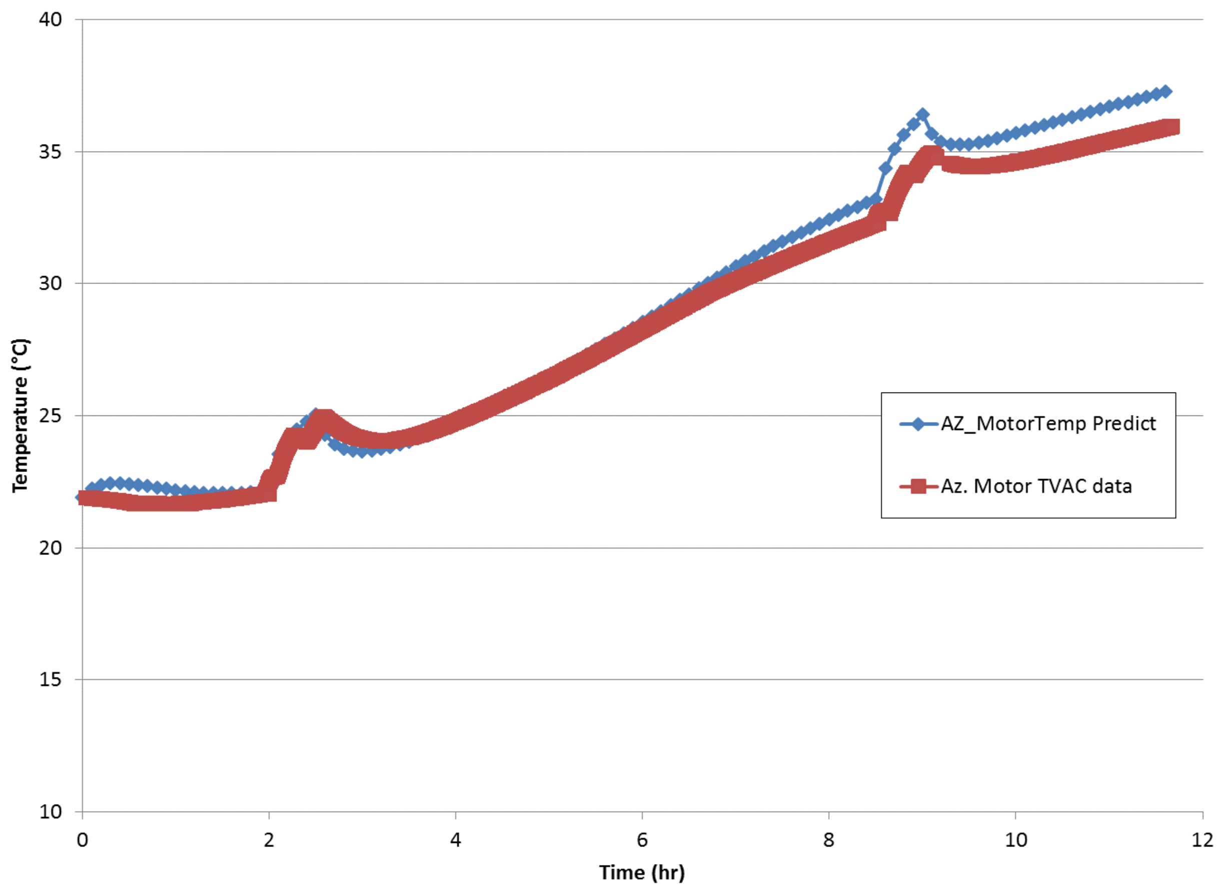
Spectrometer thermal shroud covered in aluminized Kapton (SA is mounted in a GSE fixture for testing)



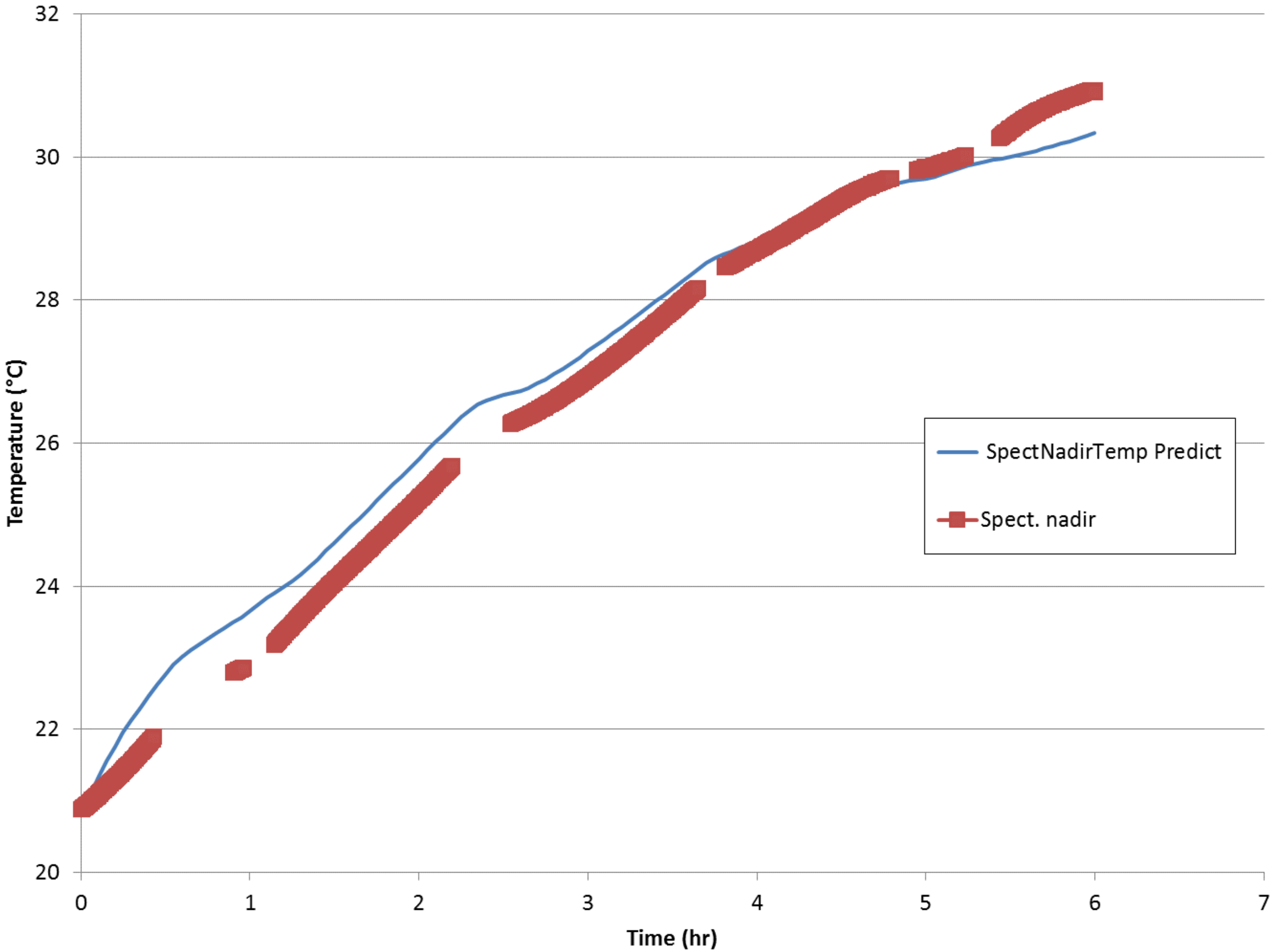
Azimuth Motor Power



Azimuth Motor Temperature Correlation

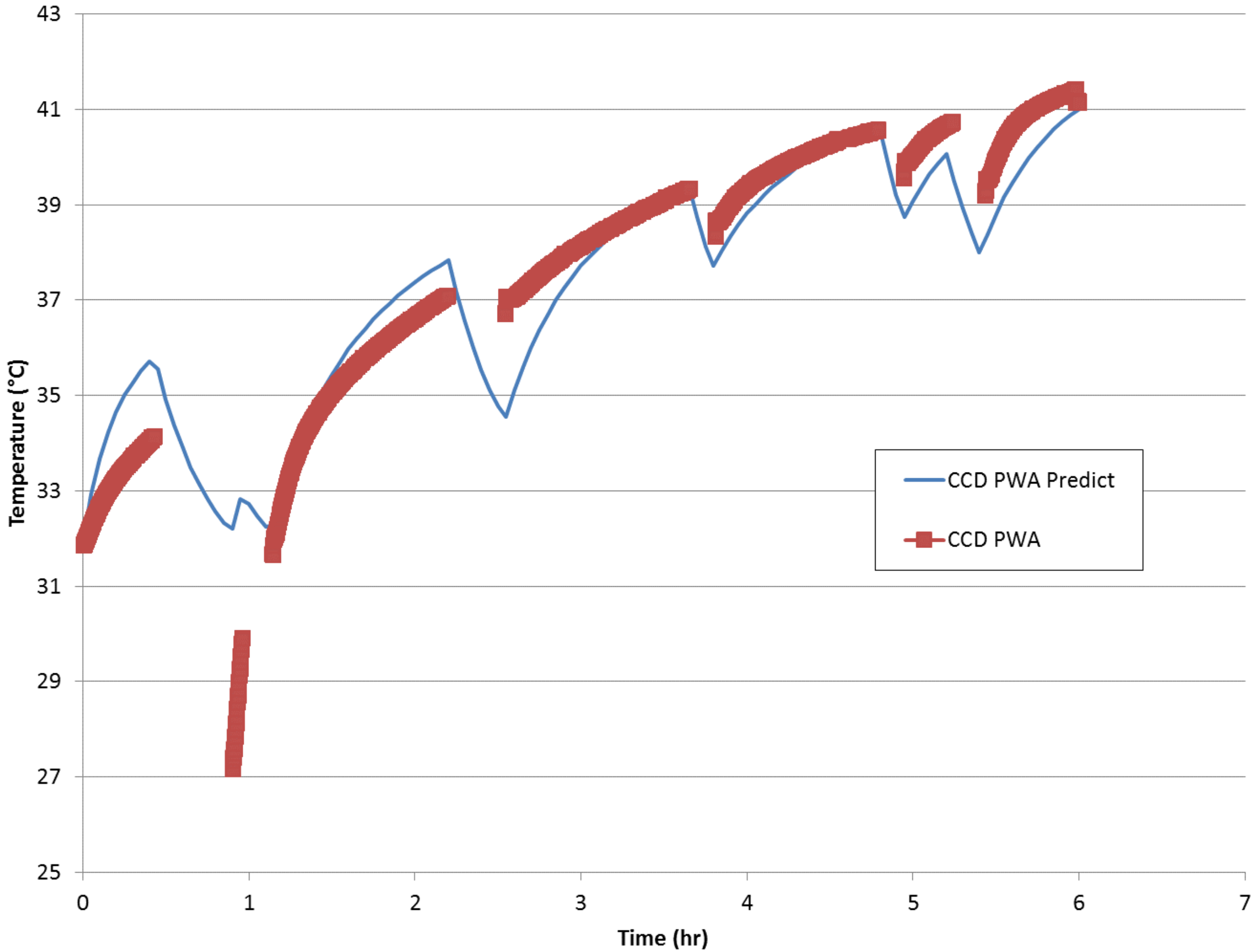


TEC Case1

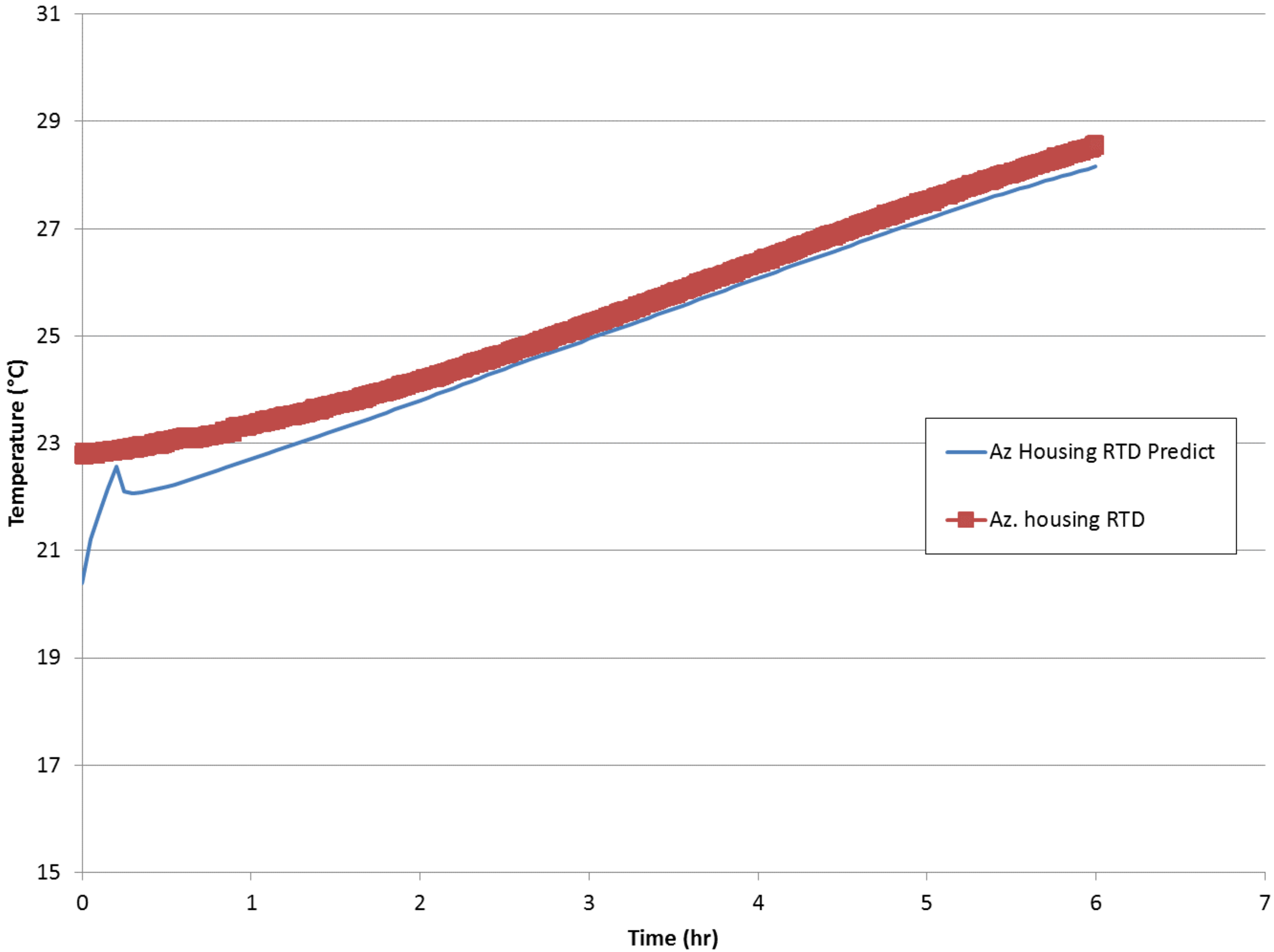


32
30
28
26
24
22
20
Temperature (°C)
0
1
2
3
4
5
6
7
Time (hr)
SpectNadirTemp Predict
Spect. nadir

TEC Case1


43
41
39
37
35
33
31
29
27
25
Temperature (°C)
0
1
2
3
4
5
6
7
Time (hr)
CCD PWA Predict
CCD PWA

TEC Case1


31
29
27
25
23
21
19
17
15
Temperature (°C)
0
1
2
3
4
5
6
7
Time (hr)
Az Housing RTD Predict
Az. housing RTD